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the diffusion of the KCl from the interior of the egg to the outside solution is removed.

This theory holds probably for all cases of the second group of phenomena of antagonism, namely where salts (and possibly acids) in general antagonize the injurious action of an electrolyte. It must remain for further investigations to decide whether it holds also for the first group of cases of antagonism where the injurious action of high concentrations of a salt with a monovalent cation (e.g., NaCl) is inhibited by traces of a salt with a bivalent cation (e.g., CaCl_2). The two groups of phenomena are in one respect the converse of each other, since in the first group the efficiency of the antagonistic action increases with the valency of the cation, while in the second group the antagonistic action increases with the valency of the anion of the antagonistic salt.

¹ Loeb, *Archiv ges. Physiol., Bonn*, **88**, 68 (1901); *Amer. J. Physiol.*, **6**, 411 (1902).

² Loeb, *Archiv ges. Physiol. Bonn*, **107**, 252 (1905).

³ Loeb, *Biochem. Zs.*, **47**, 127 (1912).

⁴ Osterhout, *Science*, **35**, 112 (1912); *Bot. Gaz., Chicago*, **59**, 317 (1915).

⁵ Loeb and Wasteneys, *Biochem. Zs.*, **31**, 450 (1911).

⁶ Loeb, *Ibid.*, **43**, 181 (1912).

⁷ Loeb and Wasteneys, *Ibid.*, **33**, 489 (1911); **39**, 167 (1912).

THE NITROGEN PROBLEM IN ARID SOILS

By Chas. B. Lipman

COLLEGE OF AGRICULTURE, UNIVERSITY OF CALIFORNIA

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Standing eminent, if not preëminent, everywhere, in considerations of soil fertility, the nitrogen problem is especially so under arid soil conditions. The acuteness of the situation in the latter has been recognized, however, by neither the scientist nor the practical man until recently when certain investigations on the one hand, and certain field manifestations on the other, have caused to stand out in sharp relief the nitrogen question from among others in California's soil puzzles. It is with reference to some of these recent findings, and their bearing on problems of soil fertility in California, that this brief paper is written as a forerunner of more detailed discussions soon to appear elsewhere.¹

Considering only the average nitrogen-content of California soils, as based on a thousand or more analyses, the student of the subject does not obtain a true picture of the paucity in nitrogen which characterizes our truly arid soils. For many of our soils are situated in regions of heavy winter rainfall and produce a luxuriant spring growth;

hence their nitrogen-content, owing to the large supply of decaying organic matter, may compare very favorably with that of an average soil of the humid region. In our truly arid soils, however, which receive fifteen inches of rainfall per year or less, it is quite the usual thing to find the total nitrogen supply below 0.05% in the air-dry surface soil. Frequently, indeed, under the conditions of the San Joaquin Valley the percentage of total nitrogen in the surface soil may be no more than 0.01% or 0.02%. Therefore, even if all of this nitrogen could be rendered available for assimilation by the plant, the soil could not be expected to produce profitable crops for more than a few years. Fortunately, the roots of plants can draw more or less freely on the nitrogen supply of the soil below the first foot in depth, and thus crops have been produced at times on soils manifestly deficient in nitrogen. It must be remembered, however, that, even in arid soils in which we commonly find nitrification proceeding at the remarkable depth of six feet below the surface, nitrification and hence the available nitrogen supply decreases in intensity rapidly with increasing depth. As a result of a total supply of nitrogen which is too meager, coupled with the relatively small fraction thereof which is rendered available as is pointed out below, nitrogen starvation with its various manifestations in different plants is one of the prominent problems of soil fertility in California, and particularly in case of nonleguminous perennial plants. To illustrate this, it may be mentioned that it has frequently been found impossible to carry young fruit trees through one season of growth in the San Joaquin Valley on soils which are otherwise well supplied with plant food elements, for lack of a proper nitrogen supply.

More frequent even than the total starvation of crop plants on our typically arid soils is the occurrence of plants which languish for several years because of an insufficient supply of available nitrogen. With my coworkers I have obtained experimental and observational data, to appear in detail later as above indicated, which point significantly to a probable causal relationship between the lack of usable nitrates in the root zone and many features of backwardness or disease in our crop plants. These data indicate, almost without exception in the soils studied, that the lack of available nitrogen referred to is to be accounted for in one or more of four ways: 1st, a lack of sufficient nitrogen in the soil in toto; 2d, a feeble nitrifying power of the soil; 3d, accumulation of nitrates in the dry surface crust of the soil in which they can not be used by the feeding roots; and 4th, denitrification of nitrates produced within or added to the soil.

Our investigations point to the conclusion that the second cause,

with certain qualifications soon to be indicated, is the most prominent of the four mentioned in connection with the nutritional problems of our crops. We are therefore in a position to confirm, as a result of our studies on truly arid soils, Stewart's² statement with respect to the intensity of nitrification in them, which was based on studies of the more distinctly semi-arid soils of Utah. While we possess ample evidence in support of Stewart's contention in the respect noted, I feel constrained to state that Stewart's criticism of Hilgard's explanation on the humus and humus-nitrogen question as between humid and arid soils is unwarranted by the facts, as we hope to show in detail in our forthcoming publications. The qualification which needs to be made with reference to our assertion as to the feeble nitrifying power of arid soils is that this power is more distinctly relatively rather than absolutely feeble. Thus we have found that some forms of nitrogen are very readily nitrified by certain arid soils which are not capable of nitrifying other forms of nitrogen at all. For example, the nitrogen of steamed bone-meal or cotton-seed meal or even of sulphate of ammonium is efficiently transformed into nitrate by many of our soils, which will not only produce no nitrate in a month's incubation period out of dried blood or high-grade tankage, but will even cause a loss of nitrate from that already contained in the soil. It appears further that the forms of nitrogen which nitrify most readily in humid soils give the most unsatisfactory results in arid soils as a general rule.

The nutritional factor contributing to the unsatisfactory growth of our crop plants is evidently then, in general, the soil's lack of power to transform enough of its own nitrogen supply or of the supply added in fertilizers or manures into a usable form. We must now give consideration to the theoretical aspects of the reasons underlying the condition just mentioned. There can be but little question that the feeble powers of the nitrifying flora of arid soils is primarily to be attributed to a deficiency in the supply of readily decayed organic matter in such soils. Inasmuch as the organic matter serves as a source of energy for the microorganisms, its initial small supply in virgin soils of this region coupled with the readiness with which it is depleted by oxidation, must operate to enfeeble and perhaps destroy the nitrifying bacteria. When we remember how small a supply of organic matter we start with in our soils and further that long hot dry seasons are the best of conditions for its dissipation through oxidation, it is small wonder that soil management by methods intended for application under eastern conditions should so far intensify the process, by constant tillage, that the necessary energy supply for the nitrifying bacteria should soon be so low as

to render impossible the proper activation of those organisms. To all such direct damage to the soil must be added the indirect damage to the water and air supply necessary for the bacteria which follows the loss of organic matter from soils.

Still other considerations of a theoretical nature enter into the problem. These are concerned with the causes for the unsatisfactory nitrification of the nitrogen in dried-blood, for example. We have noted in all of our experiments that ammonification of dried-blood nitrogen may proceed with vigor in the soils in question while no nitrate is produced. It appears now that in soils which produce ammonia most energetically from dried-blood nitrogen that the nitrifying bacteria are deleteriously affected by the ammonium carbonate and gaseous ammonia which the soils in question liberate in large quantity. Whether this speculation be correct or incorrect will appear from experiments which are now in progress. It appears certain however, regardless of the outcome of these experiments, that the fermentation of dried blood proceeds very differently in the 'normal' and the 'abnormal' soils which represent respectively those which nitrify the nitrogen of dried blood and those which do not. In the former soils no odor of ammonia is ever noted in the soil cultures and no other odors but those of active soil are encountered. In the latter soils not only is ammonia given off in large quantities, but it is accompanied by ill-smelling gases resulting from putrefaction.

The brief space of this paper precludes the possibility of a more detailed discussion of the large amount of experimental data which we have accumulated in our experiments with both humid and arid soils; but it may suffice here to point out some of their practical bearings.

1. The addition and maintenance of a good supply of organic matter by green manuring or by the use of barnyard manure must be practiced on all soils deficient in nitrogen and organic matter.

2. Nitrogenous fertilizers when employed on such soils must be either of the low-grade organic variety such as steamed bone meal, cottonseed meal, and sewage sludge, or else sulphate of ammonium must be used.

3. The overheating of the soil, excessive evaporation of moisture, and oxidation of organic matter should be prevented through the use of some kind of straw or manure mulch. This is to be regarded as one of the most important measures for present and future soil management in California orchards and vineyards, when nitrogen and organic matter are deficient.

¹ *Univ. Cal. Pub., Bull. Cal. Agric. Exp. Sta.*

² The Intensity of Nitrification in Arid Soils, *Proc. Amer. Soc. Agron.* 4, 132 (1912).